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सिंचाई उपस्कर और तंत्र — सिंचाई दक्षताओं के मूल्यांकन — मार्गदर्शी सिद्धान्त

Indian Standard

IRRIGATION EQUIPMENT AND SYSTEMS — EVALUATION OF FIELD IRRIGATION EFFICIENCIES — GUIDELINES

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
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FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards after the draft finalized by the Irrigation Equipment and Systems Sectional Committee had been approved by the Food and Agriculture Division Council.

Evaluation of the performance of irrigation system is made in terms of irrigation efficiencies. Irrigation efficiencies are used to:

- — determine how effectively the system is operating and can be operated;
- — obtain information, that will assist in designing other systems;
- — enable comparison of various systems and operating procedures as a basis for economic decisions.

Many a time the terms used in irrigation technology have multiple meanings. In view of this, the terminology used in irrigation efficiencies as well as their evaluation procedure have been defined in this standard.

In the preparation of this standard, assistance has been obtained from Central Soil Salinity Research Institute, Karnal and Haryana Agricultural University, Hissar.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*).' The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

IRRIGATION EQUIPMENT AND SYSTEMS — EVALUATION OF FIELD IRRIGATION EFFICIENCIES — GUIDELINES

1 SCOPE

1.1 This standard lays down the guidelines for evaluation of field irrigation efficiencies in respect of the following irrigation methods:

i) Border strip,
ii) Check basin,
iii) Furrows,
iv) Sprinkler, and
v) Drip.

This standard also includes the terminology on field irrigation efficiency, characteristic soil moisture, characteristic irrigation time and characteristic irrigation curve that are used for evaluating irrigation efficiency.

2 TERMINOLOGY

2.0 For the purpose of this standard the following definitions shall apply.

2.1 Soil Moisture Characteristics

2.1.0 The following terms shall be used to describe the soil moisture status or soil moisture characteristics.

2.1.1 *Soil Moisture*

Soil moisture may be expressed as a percentage of dry mass of soil, percentage of volume of soil or equivalent surface depth of water per unit depth of soil. Generally depth of water per unit depth of soil is the most convenient measurement for irrigation evaluation and management.

2.1.2 *Field Capacity* (*FC*)

It is defined as the moisture remaining in a soil following wetting and natural drainage until free drainage has practically ceased. It is also referred as field moisture capacity, normal field capacity, normal capacity, capillary capacity, maximum field carrying capacity, or effective water holding capacity.

2.1.3 *Wilting Point* (*WP*)

The moisture content of soil after the plant can no longer extract moisture at a sufficient rate to meet its evapotranspiration demand. The wilted leaf cannot recover overnight or when placed in a saturated environment. It is also known as permanent wilting percentage or wilting coefficient.

2.1.4 *Available Soil Moisture Capacity* (*AMC*)

It is defined as the moisture that can be held in the soil between field capacity and wilting point for a given crop root zone.

2.1.5 *Available Soil Moisture* (*SM*)

It is the difference between the actual soil moisture content in the root zone soil and the wilting point at any given time.

2.1.6 *Soil Moisture Deficit* (*SMD*)

It is the difference between field capacity and the actual moisture in the soil at any given time for a given crop root zone.

2.1.7 *Management Allowed Deficit* (*MAD*)

It is defined as the desired soil moisture at the start of irrigation. MAD is expressed as a percentage of the AMC or as the corresponding SMD. It is related to the desired soil moisture stress for the crop-soil-watar-weather system. Irrigation is generally scheduled when SMD equals MAD.

2.2 Irrigation Time Characteristics and Characteristic Curves

2.2.1 *Application Time* (*Ta*)

It is duration of time water flows into or is otherwise applied to an area.

2.2.2 *Advance Time* (*T av*)

It is the duration of time required for the water front to flow from the upstream end to the downstream end of a field after water is turned on.

2.2.3 *Rate of Advance*

It is the distance water front traverses in a particular time after water is turned on.

2.2.4 *Advance Curve*

It is a plot of time after water is turned on versus the distance the water front traverses.

2.2.5 *Recession Time*

It is the duration of time required for water to disappear from the entire field surface after the water is turned off.

2.2.6 *Rate of Recession*

It is the distance from which water front disappeared from the field surface after water was turned off in a particular time after water is turned on.

2.2.7 *Recession Curve*

It is a plot of time after water was turned on to the time the water disappeared from the field surface versus the distance water front disappeared.

2.2.8 *Lag Time*

It is the duration of time required for water to disappear from the upstream end of a field after the water was turned off.

2.2.9 *Opportunity Time*

It is the duration of time water is on the soil surface with opportunity to infiltrate. It is equal to the time interval between the recession curve and advance curve.

2.2.10 *Advance Ratio*

It is the ratio of time it takes a water stream to advance to the downstream end of a field to the time water is at the downstream end.

2.2.11 *Infiltration Characteristics of Soil* — *See* 2.2.11.1 to 2.2.11.6.

2.2.11.1 *Instantaneous infiltration rate*

It is the rate at which water enters into the soil at a particular time after initial wetting.

2.2.11.2 *Accumulated or cumulative infiltration*

It is the depth of water entering into the soil at the end of a given time after initial wetting.

2.2.11.3 *Basic infiltration rate*

It is approximately constant value of infiltration rate at a prolonged period of time after initial wetting.

2.2.11.4 *Infiltration rate curve*

It is a plot of the instantaneous infiltration versus elapsed time after initial wetting.

2.2.11.5 *Cumulative infiltration depth curve*

It is a plot of cumulative infiltration versus elapsed time after initial wetting.

2.2.11.6 *Infiltration depth distribution curve*

It is a plot of the depth of cumulative infiltration at specified location in a field strip. The depth of infiltration is taken from a cumulative infiltration depth curve corresponding to the opportunity time of the specified location for surface irrigation. In sprinkler irrigation, it is a plot of depths caught on equal areas arranged in a sequence of descending depths.

2.3 Field Efficiency (FE)

2.3.1 *Field Irrigation Efficiency* (*FIE*)

It is defined as the ratio of the average depth of irrigation water which is beneficially used to the average depth of water applied.

$$\text{FIE} = \frac{\begin{array}{c}\text{Average depth of water}\\ \text{beneficially used}\end{array}}{\begin{array}{c}\text{Average depth of water}\\ \text{applied to field}\end{array}} \times 100$$

NOTE

The FIE is a general term, useful for describing the effectiveness of irrigation on a single field, especially when used for beneficial purpose other than satisfying the SMD. The amount of water used for leaching to maintain the salt balance of the root zone is also considered to be beneficially used.

2.3.2 *Application Efficiency* (*AE*)

It is the ratio of the average depth of the irrigation water stored in the root zone to the average depth of irrigation water applied. It can be expressed as:

$$\text{AE} = \frac{\begin{array}{c}\text{Average depth of water}\\ \text{stored in the root zone}\end{array}}{\begin{array}{c}\text{Average depth of water}\\ \text{applied}\end{array}} \times 100$$

2.3.3 *Application Efficiency Absolute Low* (*AELA*)

It is the actual efficiency achieved with a given system and is expressed as a ratio of the minimum depth of water stored in the root zone to the average depth of water applied. It can be expressed as:

$$\text{AELA} = \frac{\begin{array}{c}\text{Minimum depth of water}\\ \text{stored in the root zone}\end{array}}{\begin{array}{c}\text{Average depth of water}\\ \text{applied}\end{array}} \times 100$$

2.3.4 *Application Efficiency of Low Quarter* (*AELQ*)

It is the ratio of the average low quarter depth of irrigation water infiltrated and stored in the root zone to the average depth of irrigation water applied. The average low quarter depth infiltrated is the average of the lowest one-fourth of the measured or estimated values where each value represents an equal area of the field. It can also be expressed as:

$$\text{AELQ} = \frac{\begin{array}{c}\text{Average low quarter depth}\\ \text{of water infiltrated and}\\ \text{stored in the root zone}\end{array}}{\begin{array}{c}\text{Average depth of water}\\ \text{applied}\end{array}} \times 100$$

2.3.4.1 When the average low quarter depth of water infiltrated, exceeds SMD, the AELQ may be expressed as:

$$\text{AELQ} = \frac{\text{SMD}}{\text{Average depth of water applied}}$$

2.3.5 *Potential Application Efficiency Absolute Low* (*PELA*)

It is a measure of how well a system performs under reasonably good management when the desired irrigation is applied. It is expressed as a ratio of the minimum depth infiltrated (when equal to MAD) to the average depth of water applied:

$$\text{PELA} = \frac{\begin{array}{c}\text{Minimum depth infiltrated}\\ \text{which is equal to MAD}\end{array}}{\begin{array}{c}\text{Average depth of water}\\ \text{applied}\end{array}} \times 100$$

When SMD = MAD,
then PELA = AELQ

2.3.6 *Potential Application Efficiency Low Quarter (PELQ)*

It is a measure of how well a system performs under reasonably good management when the desired irrigation is applied. It is expressed as a ratio of the average low quarter depth infiltrated (when equal to MAD) to the average depth of water applied:

$$\text{PELQ} = \frac{\text{Average low quarter depth of water infiltrated which is equal to MAD}}{\text{Average depth of water applied when MAD just satisfied}} \times 100$$

NOTE

The difference between PELQ and AELQ is that the AELQ is a measure of the management operations and PELQ is a measure of the design Low PELQ values indicate design problems whereas low AELQ indicate operation problems.

2.3.7 *Distribution Uniformity (DU)*

It is the uniformity of infiltration (for application in case of sprinkler and trickle irrigation) throughout the field and is expressed as a ratio of the average depth infiltrated in the lowest one-quarter of the area to the average depth of infiltrated (or caught):

$$\text{DU} = \frac{\text{Average low quarter depth of water infiltrated (or caught)}}{\text{Average depth of water infiltrated (or caught)}} \times 100$$

2.3.8 *Uniformity Coefficient (UC)*

It is a statistical representation of the uniformity of sprinkler or trickle irrigation. It is expressed as the ratio of average depth of water caught (or infiltrated) minus the average deviation from this depth, divided by the average depth caught or infiltrated:

$$\text{UC} = \frac{\text{Average depth caught} - \text{Average numerical deviation from the average depth caught}}{\text{Average depth caught}} \times 100$$

OR

$$\text{UC (approx)} = 100 - 0{\cdot}8\frac{\sigma}{X}$$

where

σ = standard deviation, and

X = average catch.

2.3.9 *Emission Uniformity (EU)*

It is the uniformity of emission from trickle irrigation emitter throughout a field and is expressed as a percent of the minimum rate of discharge to the average rate of discharge per plant.

2.3.10 *Storage Efficiency (SE)*

It is the ratio of the average depth of water stored in the root zone to the average storable depth. It is used in conjunction with the distribution uniformity and application efficiency:

$$\text{SE} = \frac{\text{Average depth stored in the root zone}}{\text{Average storable depth in the root zone}} \times 10$$

3 EVALUATION PROCEDURE

3.0 The procedure for evaluation of field irrigation efficiencies for different irrigation methods shall be as follows.

3.1 Border Strip Method

3.1.1 *Test Equipment*

The following test equipments shall be used:

a) A 30 m tape, stakes and a hatchet to derive the stakes,

b) A stop watch,

c) Soil moisture measuring devices,

d) Cylinder/infiltration set,

e) Flow measuring devices such as a Parshall Flume, weirs or flow meter, etc, and

f) A surveying level.

3.1.2 *Procedure for Collection of Field Data*

The following sequence of activities shall be followed for the collection of field data and observations shall be recorded as given in Annexes A and B.

a) Select a typical site which is representative of soil.

b) Select 3 strips which may be adjacent but preferably be alternate ones. Measure the width of each strip.

c) Measure the longitudinal and cross slope of the strips.

d) Set 6 or more stakes at 10 m interval.

e) Set the flow measuring device at each strip.

f) Estimate the soil moisture deficit (*see* **2.1.6**) and record the value in Annex A. Compare the soil moisture deficit (SMD) with management allow deficit (MAD) (*see* **2.1.7**).

g) Set four or more cylinder infiltrometers in typical location.

h) Record the cumulative infiltration depth at different time at each location in Annex A.

j) Introduce a constant stream of usual size in one border strip and a larger and smaller stream in the other two strips. Record the time of start and shut off.

k) Record the width of the wetted portion.

m) Record the time when each stream reaches the respective station in Annex B (Rate of advance).

n) Record the time when water disappears from respective stations in Annex B (Rate of recession).

p) Check the adequacy of the application a day or two after, the irrigation of soil auger or probe.

3.1.3 *Evaluation of Irrigation Efficiency*

3.1.3.1 From the field data recorded in Annex A and B draw the following characteristics curves:

a) Cumulative infiltration depth curve,

b) Advance curve,

c) Recession curve,

d) Opportunity time, and

e) Infiltration depth distribution curve.

3.1.3.2 Form the graph compute the following:

a) Distribution uniformity (DU) (*see* **2.3.7**) and UC (*see* **2.3.8**),

b) Potential application efficiencies (PELA) (*see* **2.3.5**) and PELQ (*see* **2.3.6**),

c) Application efficiencies (AELA) (*see* **2.3.3**) and AELQ (*see* **2.3.4**),

d) Actual duration of irrigation, and

e) Actual stream size.

3.2 Check Basin Method

3.2.1 *Test Equipment* — Same as given in **3.1.1**.

3.2.2 *Procedure for Collection of Field Data*

The following sequence of activities shall be followed for the collection of field data and the observations shall be recorded as given in Annexes A and B.

a) Select one or two identical basins.

b) Draw a map of the basin. Measure width and length.

c) Check the soil moisture deficit (*see* **2.1.6**) at several locations and compare it with management allowed deficit (*see* **2.1.7**).

d) Record the time of start, shut off time and rate of inflow of stream.

e) Set stakes at 10 metres interval.

f) Record the time when stream reaches each station (rate of advance).

g) Mark the position of the receding water front at several places as the water level recedes after the stream flow has been shut off (rate of recession).

h) Measure the rate of infiltration.

j) Observe variations in infiltration rate within the basins. In case of non-uniform infiltration rate, relocate the stakes to obtain more uniform rate.

k) Record the depth and uniformity of penetration using a soil probe and test the adequacy of irrigation.

3.2.3 *Evaluation of Irrigation Efficiency*

From the field data recorded compute the following:

a) Opportunity time at different stations and infiltration depth distribution curve.

b) Depth applied by the formula:

Depth applied

$$= \frac{\text{Inflow stream} \times \text{Duration}}{\text{Area}}$$

c) *Distribution Uniformity* (*DU*) — Since there is no run off in check basin, compute distribution efficiency by the formula:

$$\text{DU} = \frac{\text{Average depth applied — Average depth ponded when only one-eighth of the area is exposed}}{\text{Average depth applied}}$$

d) *Potential Application Efficiencies* — PELA (*see* **2.3.5**) and PELQ (*see* **2.3.6**).

e) *Actual Application Efficiencies* — AELA (*see* **2.3.3**) and AELQ (*see* **2.3.4**).

3.3 Furrows Irrigation Method

3.3.1 *Test Equipment* — same as given in **3.1.1**.

3.3.2 *Preparation of Test Plot and Collection of Field Data*

Select a typical test plot and prepare the same in the following manner. Record the observations in Annex C and D.

a) Select three or more alternate test furrows.

b) Measure shape, size and spacing of the furrows.

c) Measure longitudinal gradient of the furrows.

d) Set stakes along the furrows at 10 m intervals. There should be a minimum of 6 stakes.

e) Install flow measuring device at zero station on all test furrows and record the size of stream in Annex C.

f) Record items 1 to 10 of Annex C and calculate the soil moisture deficit (*see* **2.1.6**) and compare it with management allowed deficite (*see* **2.1.7**).

g) Set at least three but preferably four constant flow streams of all possible range in stream sizes. If flow rates vary during test, the change should be noted. The largest stream size in litres per second should be equal to 0·6/S, where S is longitudinal gradient of the furrow in percent.

h) Record the size of stream flowing through the station, zero in each furrow in Annex C.

j) Record the time when stream reaches each station in Annex C (rate of advance curve).

k) Record the infiltration as in Annex D.

m) Observe the furrow for errosion or over flowing and estimate the maximum usable stream.

n) Observe the run off at the lower end of furrow, if any.

p) If water is present in the furrow for an appreciable time after the stream is turned off, it should be noted.

q) Record the depth of water penetration and lateral spread using a soil probe or auger.

3.3.3 *Evaluation of Irrigation Efficiency*

From the field data recorded (*see* **3.3.2**) compute the following:

a) Advance and recession curves.

b) Infiltration rate curve.

c) Opportunity time at different stations.

d) Depth of water infiltrated at different point.

e) Distribution uniformity (DU) (*see* **2.3.7**) and uniformity coefficient (UC) (*see* **2.3.8**).

f) Application efficiencies AELA (*see* **2.3.3**) and AELQ (*see* **2.3.4**).

g) Field Irrigation Efficiency (FIE) (*see* **2.3.1**).

3.4 Sprinkler Irrigation Method

This procedure is applicable for single sprinkler lateral.

3.4.1 *Test Equipment*

The following test equipments shall be used, in addition to the equipments specified in **3.1.1**:

a) A pressure gauge with pitot tube attachment;

b) 50-100 containers of known volume;

c) A measuring stick to measure depth or a 500-ml graduated cylinder to measure volume of water caught in containers;

d) A 1·5 m long flexible hose pipe having diameter appreciably larger than the outside diameter of the nozzle;

e) Manufacturers sprinkler performance chart showing relationship between discharge, pressure and wetted diameter and recommended operating pressure; and

f) A set of drill bits ranging in size from 0·4 mm to 12·5 mm in increments of 0·4 mm to act as feeler gauge to check nozzle wear.

3.4.2 *Preparation of Test Plot and Collection of Field Data*

Select a typical site so that there is no obstruction from trees or buildings. The minimum clearance should be 30 H where H is the height of obstruction. Prepare the test plot in the following manner. Record the observations as in Annex E.

a) Choose a location along the lateral. It may be either a single location at which pressure is typical for the entire system (at about 40 percent of the distance from the inlet to the terminal end) or two locations near the ends of a lateral to permit study of the effects of differences in pressure.

b) Set at least 24 collectors on a grid having spacing not exceeding 2 × 2 m. The catch containers pattern should be laid to cover two adjacent areas between three sprinklers since sprinklers may not be applying water at precisely uniform rate.

c) Determine the soil texture profile and management allowed deficit, then estimate the available moisture capacity in the root zone and check the soil moisture deficit in the catch area on the side of lateral that was not irrigated during the previous set.

d) Check and record the make and model of the sprinkler and the diameter of the nozzle.

e) Obtain the normal sprinkler spacing, duration and frequency of irrigation and record them.

f) Read and record the rated sprinkler discharge, pressure, the computed average design application rate from the system design data and manufacturer's sprinkler catalogue.

g) Check and record the size and slope of the lateral pipe and height and errectness of the risers.

h) Before starting the test, stop the rotation of the sprinklers at the test site to prevent water from entering the containers. Turn on the water to fill the laterals, when the test lateral is full, turn the pressure slowly to observe the trajectory, break up of drops and effect of wind at different pressures. Then set the pressure at the desired value for the test. Measure and record the pressure at sprinklers at several locations. Pressure should be checked at both, the beginning and end of the test. When measuring sprinkler pressure the pitot tube must be centered in the jet which impinge directly into its tip. The tip may be rocked slightly. Record the highest pressure reading while the pitot tube is being held about 3 mm from the sprinkler nozzle.

Record how long it takes each sprinkler to fill the large container of known volume. Do this by slipping the short length of hose pipe over the sprinkler nozzle and collecting the flow in the container. Measure the nozzle output several times to compute average discharge. Often the measured discharge is more than what is specified by the manufacturer. This occurs because sprinkler nozzle often erodes during the use and becomes enlarged or because the hose pipe fits too tightly and creates a syphon action. The nozzle erosion can be checked with a drill bit that has the diameter specified for the nozzle.

j) Note the wind speed and direction.

k) Empty all catch containers before starting the test, start the test by all sprinklers surrounding the test site so that they are free to rotate, and note the starting time.

m) Set outside the catchment area a container holding the anticipated amount of catch water and note the volume of water lost by evaporation.

n) While the test is in progress, check the sprinkler pressure at 20 to 40 systematically selected locations (for example at the two ends and quarter point along each lateral). On other laterals, record the maximum, minimum and the average pressures.

p) Terminate the test by either stopping the sprinklers surrounding the test site in a position such that the jets do not fall into the containers or by deflecting the jets to the ground. Note the time. Check and record the pressure and turn off the water. The most desirable duration for the test is equal to the duration of an irrigation to get the full effect of wind and evaporation. The ideal minimum duration of test should be to collect an average of about 1·5 cm in the container, and

q) Measure the depth of water in all containers.

3.4.3 *Evaluation of Irrigation Efficiency*

From the field data recorded (*see* **3.4.2**) compute the following:

NOTE

This test shall be conducted for single lateral. Before further evaluation the lateral spacing, should be decided and the depth of water application at different points estimated by appropriate overlap.

a) *Average Catch Rate* (*ACR*) — It is the average depth of water caught in the collectors in a unit time and is expressed in cm/hr.

ACR = Total catch at all grid points/ grid points.

b) *Average Low Quarter Rate* (*ALQR*) — It is the average catch rate of the lowest 25 percent values and is expressed in cm/hr.

ALQR = Total of lowest 25 percent catch 1/4 (grid points).

c) *Rate of Application* (*RA*) — The average rate of application in cm/h is computed from sprinkler discharge in litres/hour and sprinkler and lateral spacings in metre.

$$\text{RA} = \frac{\text{Measured sprinkler nozzle discharge}}{\text{Sprinkler spacing} \times \text{Lateral spacing} \times 10}$$

d) *Total Average Depth* (*D*) — The total average depth of water application shall be computed as product of average application rate (RA) and the time of application (T).

$$\text{D} = \text{RA} \times \text{T}$$

e) *Moisture Stored in the Root Zone* (*Ds*) —

It is computed as the product of soil moisture holding capacity (SMC) in cm, root zone depth (RD) in cm, and management allowed moisture deficit (MAD) in fraction.

$$\text{Ds} = \text{SMC} \times \text{RD} \times \text{MAD}$$

f) *Efficiency Reduction due to Change in Pressure* (*ER*)

$$\text{ER} = \frac{0{\cdot}2\ (\text{Maximum pressure} - \text{Minimum pressure})}{\text{Average system pressure}}$$

g) *Distribution Uniformity* (*DU*)

$$\text{DU} = \frac{\text{ALQR}}{\text{ACR}} \times 100$$

h) *Uniformity Coefficient* (*see* **2.3.8**).

j) *Potential Application Efficiency Low Quarter* (*PELQ*) — (*see* **2.3.6**).

k) *System Potential Application Efficiency Low Quarter* (*SPELQ*) — The ratio of the average low quarter sprinkler discharge to the average sprinkler discharge approximately equals (1·0 − ER). Therefore, the system PELQ shall be computed by:

$$\text{SPELQ} = (1{\cdot}0 - \text{ER}) \times \text{Test PELQ}$$

m) *Application Efficiency Low Quarter* (*AELQ*) — Whenever irrigation exactly satisfies the SMD, in the least watered areas, AELQ equals PELQ, but when excess water is applied, then the AELQ is computed as the ratio of moisture stored in the root zone (Ds) and total average depth (D):

$$\text{AELQ} = \frac{\text{Ds}}{\text{D}}$$

3.5 Drip or Trickle Irrigation Method

3.5.1 *Test Equipment*

The following test equipments in addition to the test equipments specified in **3.1.1** shall be used:

a) Pressure gauge with 'T' adopters or the temporary installation at either end of the lateral hoses.

b) Graduated cylinder of 250-ml capacity.

c) Funnel with 10-15 cm diameter.

d) Manufacturer's emitter performance charts showing the relationship between discharge and pressure and recommended operating pressures and filter requirements.

e) Sheet metal or plastic trough 1 m long for measuring the discharge from several outlets in a perforated hose simultaneously or the discharge from 1 m length of porous tubing (A piece of 2 or 4 cm diameter PVC pipe cut in half lengthwise, makes a good trough).

3.5.2 *Preparation of Test Plot and Collection of Field Data*

Select a typical site and prepare the test plot in the following manner. Record the observations as in Annex F. The procedure is suitable for evaluating systems with emitters and perforated or porous laterals.

a) Record the soil and crop characteristics in items 4 and 5 of Annex F.

b) Calculate the duration, frequency of irrigation, and management allowed deficit. Record the observations in item 6 of Annex F.

c) Record the pressure at the inlet and outlet of the filter in item 7 of Annex F.

d) Record the emitter and lateral hose characteristic in items 8, 9, 10 and 11 of Annex F.

e) Locate four emitter laterals along an operating manifold; one should be near the inlet and two near the third points and the fourth near the outer end.

f) Record the system discharge rate and the number of manifolds and blocks. The number of blocks is the total number of manifolds divided by the number of manifolds in operation at any one time.

g) For laterals having individual emitters, measure the discharge at two adjacent emission points (denoted as A and B in item 15 of Annex F at each of four different trees or locations on each of the four selected test laterals. Collect the flow for a number of full minutes (1, 2, 3, etc.) to obtain a volume between 100 and 250 ml for each emission points. Convert each reading to millilitre per minute before entering in item 15 of Annex F.

The above steps will produce eight pressure readings and 32 discharge volume at 16 different plant locations for individual emission points used in widespread crops with two or more emission points per plant. For perforated hose pipe or porous tubing, use one meter trough and collect discharge readings at each of the 16 locations described above. Since these are already averages of 2 or more outlets, only one reading shall be recorded at each location.

h) Measure and record in item 17 of Annex F the water pressure at the inlet and down stream end of each lateral tested in item 17 of Annex F under normal operation. On the inlet end this requires disconnecting the lateral hose, installing the pressure gauge and reconnecting the hose before reading the pressure. On the down stream end, the pressure can be read after connecting the pressure gauge.

j) Check the percentage of the soil that is wetted at one of the three locations on each test lateral and record in item 18 of Annex F. It is desirable to select a tree at a different relative location on each lateral. Use the probe, soil auger or shovel for estimating real extent of the wetted zone at 15 to 30 cm below the surface around each tree. Determine the percentage wetted by dividing the wetted area by the total surface between four trees.

k) If an interval of several days between irrigation is being used, check the SMD in the wetted volume near a few representative trees in the next block to be irrigated and record in item 20 of Annex F.

m) Determine the minimum lateral inlet pressure (MLIP) along each of the operating manifolds and record in item 21 of Annex F. For a level or uphill manifolds, the MLIP, will be the far end of the manifold. For down hill manifolds it is often about two-thirds down at manifold. For the manifold on undulating terrain, it is usually on a knoll or high point.

n) Determine the discharge correction factor (DCF) in item 22 of Annex F to adjust the average omission point discharges for the tested manifolds. This adjustment is needed if the tested manifold happens to be operating with a higher or lower MLIP then the average system MLIP.

p) Determine the average and adjust average emission point discharge according to the equations in item 23 and 24 of Annex F.

3.5.3 *Evaluation of Efficiency*

From the field data recorded (*see* **3.5.2**) compute the following:

a) *Average application depth* (D_{av}) — The average depth per irrigation to the wetted area shall be useful for estimating management allowed deficit and shall be computed by:

$$D_{av} = \frac{NQH}{10\,A}$$

where

D_{av} = average depth per irrigation, in cm;

N = number of emission points per tree;

Q = adjusted average emission point discharge for system as estimated in item 24 of Annex F, in 1 ph;

H = hours of operation per irrigation;

A = average wetted area, item 18, of Annex F, in sqm per tree.

b) *Overall average depth* (D_a) — It shall be computed by substituting the plant spacing for wetted area in the formula given in **3.5.3** (a):

$$D_a = \frac{N \times Q \times H}{10\,[\text{ Total area (Row spacing, m} \times \text{plant spacing, m) }]}$$

c) *Volume of water required per day per plant* — The average volume of water required in litres per hour per day per plant shall be computed from the average discharge in litres per day, at each emission point, the number of emission point per tree, the number of hours of operation per irrigation, and the irrigation interval in days.

Average daily requirement of water, lpd, per tree

$$= \frac{NQH}{\text{Irrigation interval in days}}$$

d) *Efficiency reduction factor* (*ERF*) — If the manifold inlet pressures are not properly set, the overall system potential application efficiency will be lower than test potential application efficiency. Estimate the efficiency reduction factor from the minimum lateral inlet pressure (MLIP) along each manifold by:

i) $$\text{ERF} = \frac{\text{Average MLIP} + 1{\cdot}5 \times \text{Minimum MLIP}}{2{\cdot}5 \times \text{Average MLIP}}$$

ii) $$\text{ERF} = \left[\frac{\text{Minimum MLIP}}{\text{Average MLIP}}\right]^n$$

where

n = emitter discharge exponent.

e) *Emission uniformity* (E_u)

$$E_u = \frac{\text{Adjusted average low quarter emission point discharge rate per plant}}{\text{Adjusted average system emission discharge per plant}} \times 100$$

NOTE

The average of the lowest quarter (Item 23 of Annex F) shall be used as the minimum for each of the four emitters per plant.

f) *Potential application efficiency low quarter* (*PELQ*) — When irrigation is applied every day, estimate soil moisture deficit from weather data or information derived from evaporation devices. In order to provide for under estimates, as a general rule, 10 percent more water than the estimated SMD or evapo-transpiration should be applied to the least watered areas. The PELQ under full irrigation shall be estimated by:

$$\text{PELQ} = 0{\cdot}9\,E_u$$

$$\text{System PELQ} = \text{ERF} \times \text{Test PELQ}$$

g) *Application efficiency low quarter* (*AELQ*) — The effectiveness of a drip system shall be estimated by how much of the applied water is stored in the root zone and is available for consumptive use by the plants. Since there are essentially no opportunities for losses due to evaporation or drift, for inadequate irrigation in which the least watered areas are under-irrigated.

$$\text{System AELQ} = \text{ERF} \times \text{Test } E_u$$

However, if excess water is applied in the least watered areas:

System AELQ

$$= \frac{\text{SMD in wetted areas}}{\text{Average depth applied to wetted area (} D_{av} \text{)}} \times 100$$

h) *Overall minimum depth applied* (D_n) — The overall average depth applied to the total area (D_a) multiplied by system

PELQ (or AELQ) shall be computed by:

$$D_n = \frac{D_s \times \text{System PELQ (or AELQ)}}{100}$$

NOTE — Overall minimum depth applied, D_n, shall be used in irrigation scheduling. Use AELQ for under irrigation or when AELQ > PELQ.

4 IRRIGATION EFFICIENCY REQUIREMENT

4.1 The major physical requirements and potential application efficiency of different irrigation techniques shall be as given in Table 1.

Table 1 Major Physical Requirements and Potential Application Efficiencies of the Low Quarter for the Basic Irrigation Techniques

Irrigation Method	Physical Requirement at Site					
	Soil Uniformity	Infiltration Rate	Ground Slope	Water Supply	Labour Intensity	Potential Application Efficiency PELQ
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Basin	Uniform within each basin	Any	Level, or graded	Large intermitent	High at frequent intervals	60-85
Basin check	Uniform within each basin	All but extremes	Mild & smooth	—do—	High at infrequent intervals	60-80[1]
Border strip	Uniform within each strip	—do—	—do—	—do—	—do—	70-85[1]
Furrow or corrugation	Uniform along each furrow	All but very rapid	Mild or contour	Medium to large intermitent	High at infrequent intervals	70-75[1]
Sprinkler	Soils may be intermixed	All but very slow[2]	Any formable slope	Small continuous	High to very low daily[3]	65-85 depending on crops raised
Trickle (drip or sub-surface)	Soil may be intermixed	Any	Any formable slope	Small continuous	Very low daily	75-90

NOTE—This table makes no allowance for control of salinity and micro-climate.

[1] Values of 90 percent can be attained under ideal conditions if runoff water is reused.

[2] Except for centre pivot and travelling sprinkler, which are best suited to use on soils that have medium and high infiltration rates.

[3] Labour inputs range from high intensity for hand move, moderate for mechanical move, to low for automatic sprinkle irrigation system.

ANNEX A

(*Clauses* 3.1.2, 3.1.3.1 *and* 3.2.2)

BORDER STRIP IRRIGATION INFILTRATION EVALUATION

1 Location
2 Observer
3 Date
4 Crop
5 Root zone depth, m
6 Management allowed deficit, cm
7 Soil texture
8 Available moisture, cm/m
9 Soil moisture deficit, cm
10 Crop history
11 Infiltration measurement

Infiltration Readings

Station—A

Sl No.	*Time,* min	*Infiltration,* cm	*Watch*	*Difference*	*Cumulative Time*	*Depth*	*Difference*	*Cumulative Time*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)

12 Remarks

ANNEX B

(*Clauses* 3.1.2, 3.1.3.1 *and* 3.2.2)

BORDER STRIP IRRIGATION WATER ADVANCE AND RECESSION EVALUATION

1 Location
2 Observer
3 Date
4 Crop and condition
5 Border condition
6 Border: soaking depth, m
7 Strip width, m
8 Wetted width, m
9 Slope, percent
10 Irrigation duration, h
11 Frequency
12 Water spread
13 Strip No.
14 Stream size
15 Application time, *T* and advance time, T_{adv}
16 Measurement of opportunity time:

Station No.	*Distance in* m *from upstream end of strip*	*Rate of Advance*		*Rate of Recession*		*Opportunity time,* ($T_{adv} - T_x + T_r$)	*Cumulative infiltration depth*
		Watch time when stream reaches respective station	*Duration of time after the water was turned on,* T_x	*Watch time when water disappears from respective stations*	*Duration of time after the water was turned off,* T_r		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)

ANNEX C

(*Clause* 3.3.2)

FURROW IRRIGATION WATER ADVANCE EVALUATION

1 Location
2 Observer
3 Date
4 Crop
5 Root zone depth, m
6 Row spacing, cm
7 Length, m
8 Soil texture
9 Available moisture, cm/m
10 Soil moisture deficit, cm
11 Irrigation duration, h
12 Frequency, days
13 Management allowed deficit, cm and percent
14 Furrow No.
15 Stream size
16 Application time (*T*) and advance time, (T_{adv})
17 Measurement of opportunity time:

Station No.	*Distance in* m *from upstream end of strip*	*Rate of Advance*		*Rate of Recession*		*Opportunity time,* ($T_{adv} - T_x + T_r$)	*Cumulative Infiltration Depth*
		Watch time when stream reaches respective station	*Duration of time after the water was turned on,* T_x	*Watch time when water disappears from respective stations*	*Duration of time after the water was turned off,* T_r		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)

ANNEX D
(*Clause* 3.3.2)

FURROW INFILTRATION EVALUATION

1 Location
2 Observer
3 Date
4 Furrow
  a) Identity
  b) Shape
  c) Condition
5 Soil texture
6 Moisture, percent
7 Slope, percent
8 Measurement of flow intake rate:

Time Watch (1)	*Difference, Min* (2)	*Cumulative, Min* (3)	*Station A* (4)	*Flow Rate, litres per second* (lps) (5)	*Station B* (6)	*Flow Rate,* lps (7)	*Intake* lps/10 m (8)

9 Accuracy range
10 Remarks

ANNEX E
(*Clause* 3.4.2)

PROFORMA FOR DATA COLLECTION RELATING TO SPRINKLER IRRIGATION EVALUATION

1 Location
2 Observer
3 Date
4 Crop
5 Root zone depth, m
6 Management allowed deficit, percent
7 Management allowed deficit, cm
8 Soil
  a) Texture
  b) Available moisture
  c) Moisture depth, cm
9 Sprinkler
  a) Make
  b) Model
  c) Nozzle
10 Sprinkler spacing, cm
11 Irrigation duration, h
12 Rated sprinkler discharge, lpm at kg/cm² giving cm/h
13 Lateral: diameter
14 Slope, percent
15 Riser height, cm
16 Actual sprinkler pressure and discharge rates:

Sprinkler Location No. of Test Lateral (1)	*Initial Pressure,* kg/cm² (2)	*Final Pressure,* kg/cm² (3)	*Catch Volume,* litres (4)	*Catch Time* (min *or* sec) (5)	*Discharge,* lpm (6)

17 Wind direction relative to container grid:
  Initial During Final
18 Wind speed (km/h):
  Initial During Final
19 Container grid test data
  a) Units of volume/depth, ml/cm
  b) Container grid spacing 2 m by 2 m
  c) Test:
    Started at, Stopped at, Duration, Min

20 Evaporation from container:	Initial	Final	Loss, cm
21 Sprinkler pressure:	*Max*,	kg/cm^2,	Average, kg/cm^2
22 Remarks			

ANNEX F

(*Clause* 3.5.2)

PROFORMA FOR DATA COLLECTION RELATING TO TRICKLE IRRIGATION EVALUATION

1 Location
2 Observer
3 Date
4 Crop
  a) Type
  b) Age, years
  c) Spacing, m
  d) Root depth, m
  e) Percent area covered or shaded, percent
5 Soil
  a) Texture
  b) Available moisture, cm/m
6 Irrigation
  a) Duration, h
  b) Frequency, day
  c) Management allowed deficit, percent
  d) Management allowed deficit, cm
7 Filter pressure
  a) Inlet, kg/cm^2
  b) Outlet, kg/cm^2
  c) Loss, kg/cm^2
8 Emitter
  a) Make
  b) Type
  c) Point spacing, m
9 Rated discharge per emission point lph at kg/cm^2
13 Emission points per plant, discharging, litres per plant per day
11 Hose
  a) Diameter, cm
  b) Material,
  c) Length, m
  d) Spacing, m
12 System layout
  a) General topography
  b) Test locations
13 System discharge, lph
14 Number of manifolds and blocks
15 Discharge test volume collected in one minute

Outlet Location on Lateral		*Lateral Location of the Manifold*							
		Inlet End		*1/3 Down*		*2/3 Down*		*Far End*	
(1)		ml (2)	lph (3)	ml (4)	lph (5)	ml (6)	lph (7)	ml (8)	lph (9)
Inlet End	A								
	B								
	Average								
1/3 Down	A								
	B								
	Average								
2/3 Down	A								
	B								
	Average								
Far End	A								
	B								
	Average								

16 Pressure in Lateral inlet	kg/cm^2	kg/cm^2	kg/cm^2	kg/cm^2
17 Pressure in closed end	kg/cm^2	kg/cm^2	kg/cm^2	kg/cm^2
18 Wetted area (average)	m^2	m^2	m^2	m^2
19 Wetted area per plant	Percent	Percent	Percent	Percent

20 Estimated average soil moisture deficit in wetted soil volume, cm

21 Minimum lateral inlet pressure (MLIP) on all operating manifolds:

a) Manifold tested at:

A	B	C	D	E	F	G	Average

b) Pressure: kg/cm²

22 Discharge correction factor, DCF, for the system:

$$\text{DCF} = \frac{2\cdot5 \times (\text{Average MLIP, kg/cm}^2)}{(\text{Average MLIP, kg/cm}^2) + 1\cdot5 \times (\text{Test MLIP, kg/cm}^2)}$$

or, if the emitter discharge exponent *n* is known

$$\text{DCF} = \left[\frac{\text{Average MLIP, kg/cm}^2}{\text{Test MLIP, kg/cm}^2)}\right]^n$$

23 Average test manifold emission point discharges at kg/cm²

a) Manifold (lph)

$$= \frac{\text{Sum of all averages. lph}}{\text{Number of averages}}$$

b) Low 1/4 (lph)

$$= \frac{\text{Sum of low 1/4 averages, lph}}{\text{Number of low 1/4 averages}}$$

24 Adjusted average emission point discharges at kg/cm²

a) System (lph)

= (DCF) × (Manifold average, lph)

b) Low 1/4 (lph)

= (DCF) × (Manifold low 1/4, lph)

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